Demonstration of Submillimeter Astrophysics Technology at Caltech Submillimeter Observatory

Completed Technology Project (2013 - 2014)

Project Introduction

Detector technology developments will determine the science product of future astrophysics missions and projects, and this is especially true at submillimeter wavelengths where the science potential is just being unlocked (e.g., Herschel Space Observatory) but instruments are very far from using efficiently each photon arriving at the focal plane of telescopes. Demonstration of prototype detectors on a relatively low-cost ground-based or suborbital telescope is a key step toward their use in a major project. The Caltech Submillimeter Observatory (CSO) provides a unique, powerful, and cost-efficient test bed for proving new submillimeter detectors. Recent ‘success stories’ for submillimeter detectors featured in a space mission, but tested first at CSO, include the Herschel/SPIRE bolometer arrays (employed first in Bolocam at CSO) and Herschel/HIFI SIS mixers (developed for CSO in years prior). Looking ahead, the CSO is an ideal test bed for demonstrating novel submillimeter Kinetic Inductance Detectors (KIDs) for wide-field imaging and moderate-resolution spectroscopy, submillimeter wavefront sensing techniques which take advantage of large detector arrays, and potential breakthrough technologies such as broadband quantum-limited parametric amplifiers. Near-term science application targets include the Cerro Chajnator Atacama Telescope (CCAT), and longer-term mission targets are SPICA, Millimetron, SAFIR/CALISTO, SPIRIT and SPECS.

The following are the objectives of this project:

(1) Demonstration of 1600-element Kinetic Inductance Detector (KID) imaging array operating at 350 micron with near background-limited sensitivity, a critical development step for the Short Wavelength Camera (SWCam) on CCAT;

(2) Demonstration of 400-element KID imaging array operating at 850 micron with near background-limited sensitivity, also a critical development step for CCAT cameras;

(3) Phase-contrast wavefront sensing at 850 micron with improved sensitivity and accuracy, targeting the eventual measurement of the CCAT telescope surface.

The current worldwide state-of-the art for submillimeter imaging detectors is the U.K.’s SCUBA2 instrument, which has 5000 Transition-Edge Sensor (TES) detectors each at 450 and 850 micron. TES’s work well, but may have reached practical limits for a ground-based project in part due to the high detector cost (> $100/pixel). KIDs, on the other hand, should achieve a detector cost of <$10/pixel in the medium term and are therefore the baseline for CCAT’s short-wavelength camera SWCam, which requires 50,000 detectors. KIDs manufactured at JPL have shown background-limited performance in the lab at 350 micron, and a 400-element first-generation prototype was tested at CSO

Image Not Available

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Table of Contents

Project Introduction	1
Anticipated Benefits	2
Organizational Responsibility	2
Project Management	2
Technology Maturity (TRL)	2
Primary U.S. Work Locations and Key Partners	3
Technology Areas	3

in April 2013 (see Figure) with promising results. The SWCam detectors operate by absorbing radiation directly in the inductive element of a TiN film and are fabricated by remarkably simple lithography. 350 micron is the key band for CCAT, and the SWCam detector work to date has concentrated on this band. By re-optimizing the detailed design according to the operating background power, KIDs can work at fundamental background-limited sensitivity limits over a wide range of applications. Given that 850 micron is also an important band for CCAT, we propose to test an 850 micron imaging KID array at CSO in FY14.

In FY12 and FY13, JPL and Caltech demonstrated the first (to our knowledge) implementation of phase-contrast (or Zernike) wavefront sensing applied to a submillimeter telescope (see Figure). In this approach, the detector images the power distribution incident on the pupil (primary mirror), and the phase of the field from a point source is modulated in the image plane in order to map the wavefront in the pupil plane. The resolution in the wavefront mapping improves as the number of imaging elements available grows. The testing demonstrated basic operation of the wavefront sensor, with induced ~π/4 wavefront shifts over ~3% of the telescope surface detectable in a few minutes. This testing has been done so far at 850 micron with the (aging) SHARC2 instrument that was not originally designed for operation at that wavelength. One should be able to do much better with an improved detector.

Anticipated Benefits

Future suborbital and space submilllimeter/FIR missions will benefit from this technology. These include balloon missions and possible Probe-class mission such as CALISTO, presented to previous Decadal Survey.

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

Center Independent Research & Development: JPL IRAD

Project Management

Program Manager:

Fred Y Hadaegh

Project Manager:

Jonas Zmuidzinas

Principal Investigator:

Charles D Dowell

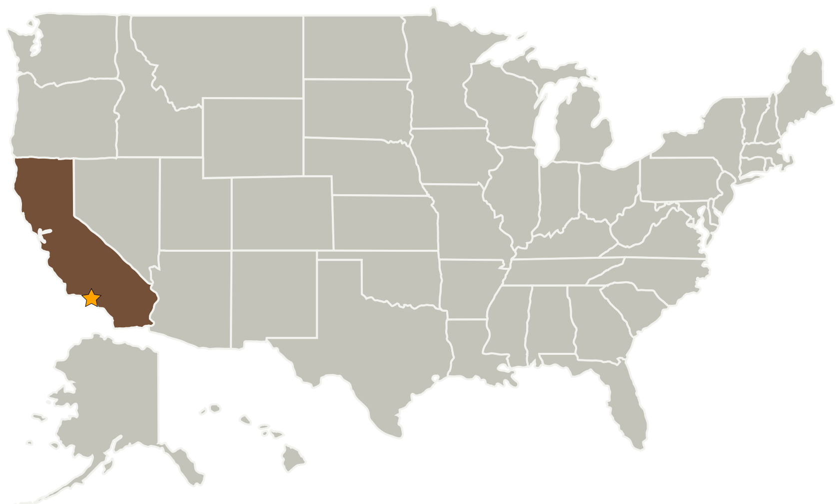
Technology Maturity (TRL)

Start: **4**
Estimated End: **5**

1 2 3 4 5 6 7 8 9

Applied Research | Development | Demo & Test

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Jet Propulsion Laboratory(JPL)	Lead Organization	NASA Center	Pasadena, California

Primary U.S. Work Locations
California

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.1 Remote Sensing Instruments/Sensors
    - └ TX08.1.1 Detectors and Focal Planes